DOCUMENT RESUME

ED 179 491 SP 011 346

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TITLE The Sequence of Reasoning Processes: The Hierarchical Organization.
PUB DATE 77
NOTE 25p.; Paper presented at the Annual Symposium of the Jean Piaget Society (7th, Philadelphia, Pennsylvania, May 19-21, 1977)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Processes; *Concept Formation; Concept Teaching; Deductive Methods; Inductive Methods; *Instructional Systems; *Learning Theories; *Logic; *Mental Development; *Organization; Problem Solving; Space; Time
IDENTIFIERS *Piaget (Jean)

ABSTRACT

A sequence of reasoning processes based on a combination of theories developed by Jean Piaget is presented. An applied theory of concept-teaching is derived from the restructuring of Piagetian theories on logical thought specifically concerned with the notions of the additive and multiplicative ordering of groups, and the four logic processes of classification, seriation, causality, and probability. These theories are combined with the dimension of topological time and space. The resultant second-order model is applied to the classroom problem of effective organization of instructional material. The case is made for the instruction of logical processes to students prior to content instruction. Diagrams and references are included. (LH)

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THE SEQUENCE OF REASONING PROCESSES: THE HIERARCHICAL ORGANIZATION

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The sequence of reasoning processes presented here is one of four cognitive structures that form a model on developmental instruction. The sequence is a combination of theories by Piaget on the development of logical thought. Specifically, Piaget's theories on 1) additive and multiplicative order of groups, and 2) four logic processes on classification, seriation, causality, and probability have been combined with the dimensions of topological space and time into a construct, which Laszlo (1972) termed a "second-order model." The sequence, then, is applied theory based on restructuring several Piagetian theories on logical thought into an instructional model.

Piaget's theories would have a greater impact on learning if used with second-order models which integrate the theories into frameworks intended for classroom instruction. There are two steps to conceptualizing a second-order model for instruction: first, a specific instructional problem is identified; and second, sources for the second-order model are selected from first-order models, here Piaget's theories on thought. Particularly, the first step can lead to the adoption of Piaget's theories in the classroom if teachers can identify with the instructional problem.

Paper presented at the Seventh Annual Symposium of the Jean Piaget Society, Philadelphia, May 19-21, 1977.

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Problem: A major problem in instruction concerns how teachers can facilitate the organization of information into concepts. Regardless of grade level, teachers tend to assume that students can organize the information they read into concepts. Most teachers give reading assignments with the organization of the information implied; for example, students are to explain Bolivia's social problems described in their textbooks. There is no instruction on how the students can attack the task to organize the information into an explanation. A serious discrepancy exists at this point in instruction between what the teacher expects and the processes the students use to organize information.

Teachers realize that students must have the idea of the concept in mind before they encounter new information in an instructional task. A common practice is to use films to introduce the concept. Unfortunately, teachers rarely have students define the images and ideas they assimilate from the film. As a result, the ideas and images provide too vague a framework for organizing most of the information.

Even if the ideas and images had been defined, the students still could not consciously process the information to develop concepts. Unless they organized the information into relationships as they assimilated it, most of the information was squandered or lost. Concept development is effected by both the loss of information and the relationships the students make from the information. For example, students form weak relationships when they associate factual information with their ideas of events, places, or whatever. Students tend to think in asso-

ciations unless they consciously learn other processes to organize information. Few middle school or senior high students could adequately explain Bolivia's problem in the hypothetical assignment stated above, because they would associate factual information when they should have followed a process for linking two dissimilar concepts in a causal relationship.

Definition of Reasoning: Reasoning is the conscious process of forming information into relationships. There are two components to reasoning:

1) the series of planned steps for organizing information into relationships; and

2) the conceptual framework formed by the relationships.

These two components are functionally interdependent since the form for the framework is inherent in the structuring action of the process. Or more simply stated, each component is defined by the other. To illustrate the interdependency, consider the output from the action of classifying information in comparison to the output from linking information in a causal relationship. The two frameworks, which are discussed on page 9, are structurally different because the information is organized into different relationships. Or reversed, the two kinds of conceptual frameworks shown in Diagram 2 depend on two different processes.

Students have to associate factual information with places, persons, or whatever to assimilate the information, but the organization of information into structured relationships is the essential step in concept development. A concept can be defined as an undifferentiated whole, or information without organization to it, which is loosely formed around an idea. The use of a reasoning process

with a concept structures the information into a framework. Therefore, instruction in reasoning processes can lead to concept development when the teacher directs the students to organize the concept into some kind of structure.

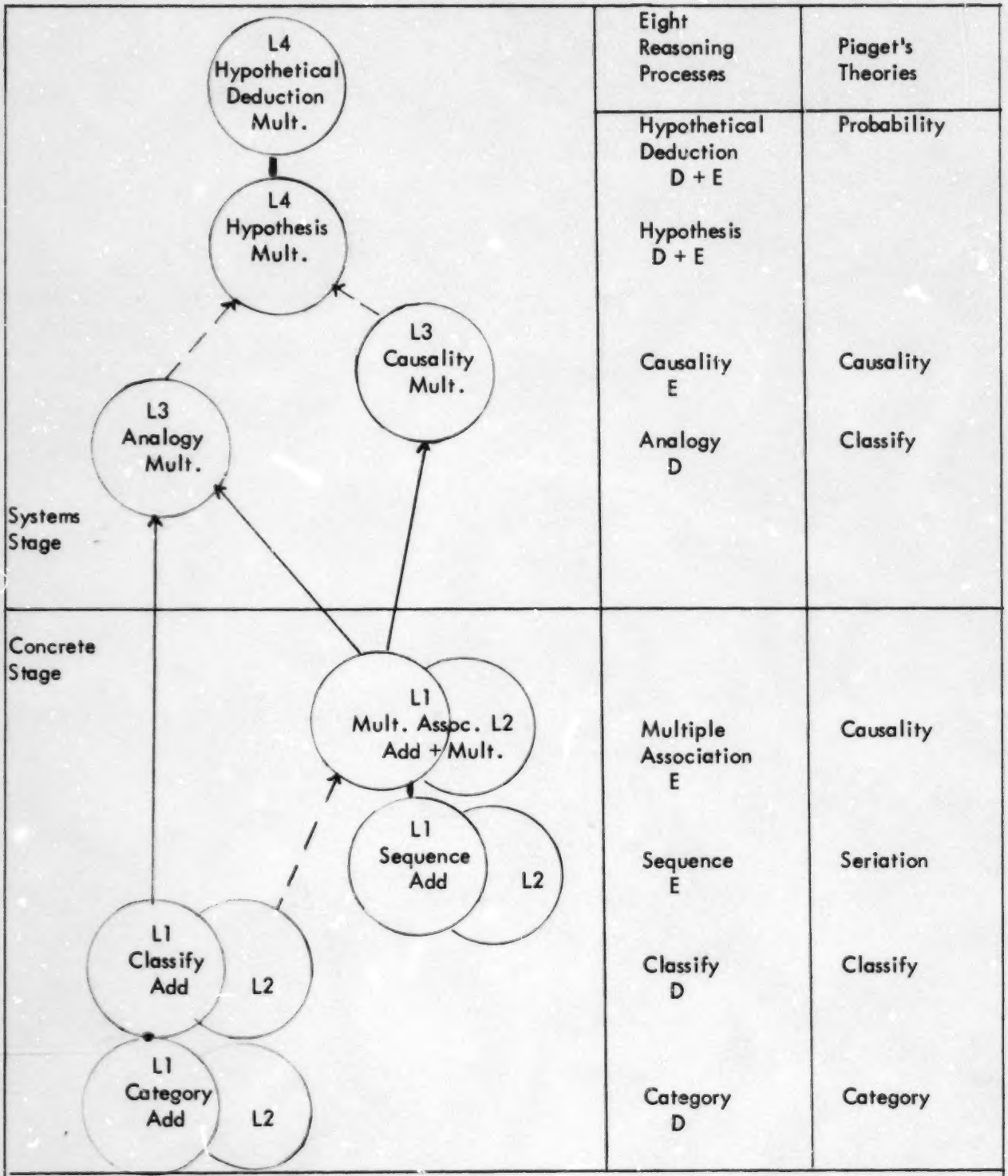
In the hypothetical assignment on Bolivia, the teacher missed the essential step in instructing the students on how to organize information into an explanation. Where a reasoning process should have been introduced, students were given the resource of the textbook, and expected to organize the information as they read it.

HIERARCHICAL ORGANIZATION

In Diagram 1 on the following page, eight reasoning processes form the cognitive structure shown in the hierarchical arrangement. This structure of processes results from a combination of Piaget's theories which have been organized according to general systems theory. The theory can be considered appropriate for constructing Piaget's theories into a second-order model since the developmental stage theory of Piaget and general systems theory both focus on 1) the organization of wholes and 2) the definition of a structure through its organization. In comparing developmental stage theory with general systems theory described by Bertalanffy (1968), Rapoport (1968), and Laszlo (1972) the following definitions characterized both theories:

1) a whole which functions as a system through the interdependency of its parts;
2) an organized complexity to the parts of the system; and

DIAGRAM 1. INTERDEPENDENCY OF THE EIGHT REASONING PROCESSES



1. L 1, 2, 3, 4 - Levels

2. Add. - Additive
   Mult. - Multiplicative

3. —— Continuity
   ----Functional Dependency

4. D - Definitive
   E - Explanative

3) an open system which is maintained by constant interchange with the environment.

In addition Piaget's developmental stage theory included

4) a progressive organization within each stage from formation to attainment; and

5) preceding structures that become part of higher structures in the transition to later stages.

These definitions provide the criteria for structuring the reasoning processes into the hierarchical system discussed on the following pages.

System: The sequence of eight reasoning processes is a system because it functions as a whole. Its parts are the reasoning processes which are composed of two components, the structuring action and the framework, which function interdependently in a process-output relationship. The interdependency between these two components of reasoning is the basis for the system. The following discussion on the levels within the hierarchy illustrates how each process combines new information with the output from preceding processes to structure more complex frameworks.

Interdependency Between Levels: The eight reasoning processes are ordered into a hierarchical structure by three kinds of interdependencies (between stages, interstage levels, and within levels) which results in the eight reasoning processes functioning as a system. Through this organization, the conceptual frameworks from preceding processes become part of later structures.

Stage: The hierarchy or reasoning processes is formed by two discrete stages, which are differentiated by the change in the student's definition of reality. Instruction during the concrete stage, which is characterized by the student's adaptation to the physical environment, is based on the student's use of language to define objects, persons, places and events which are observable. Instruction during the systems stage leads the student to conceptualize definitions of increasingly complex conceptual structures and systems. The student uses outputs of the concrete stage, which are the observable parts of a structure or system, to reorder the environment structurally.

This relationship is seen in Diagram 1. The words additive (add) and multiplicative (mult) indicate a major difference in the complexity of the structures between the concrete and systems stage. Most of the conceptual frameworks at the concrete stage are composed of additive groups or classes that define one concept. While at the systems stage, the structures are multiplicative since systems are composed of several concepts. For example, in Diagram 2, the conceptual framework for one concept, mammals, would be an output of reasoning process at the concrete stage. It is a category structure composed of groups, each based on information about animals, which have been ordered by levels into a definitive concept. This structure would be reordered into the multiplicative structure on the pyramid of life. Each of the five concepts which form the structure on the pyramid of life would be constructed from numerous groups or classes similar to the structure on mammals. (See Diagram 2 on the next page.)

Interstage Levels: While a qualitative difference exists between the four interstage levels in the different ways the student interacts with information, the outputs from preceding levels provide the information needed in the transition to higher interstage levels.

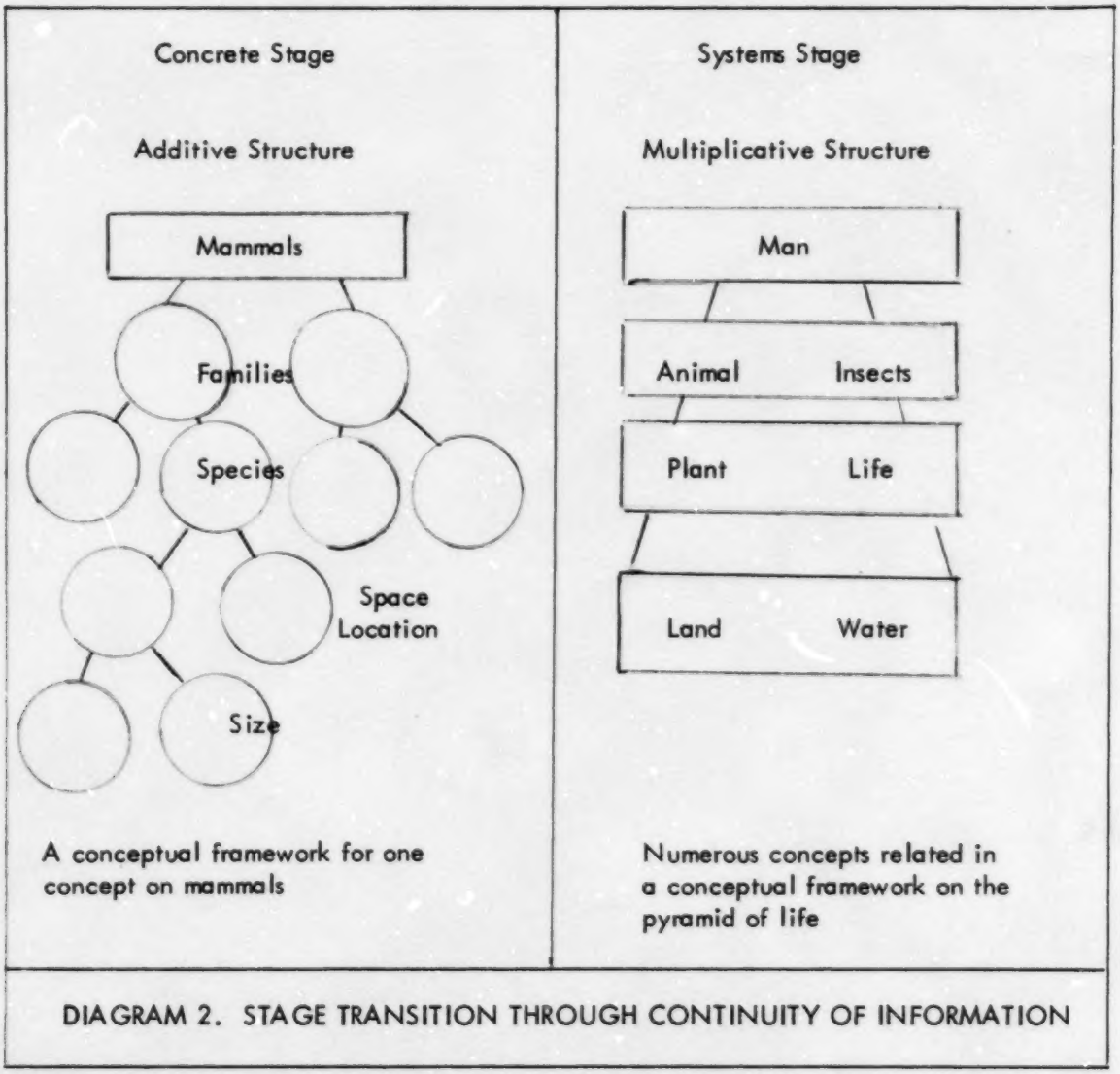


DIAGRAM 2. STAGE TRANSITION THROUGH CONTINUITY OF INFORMATION

Pre-concrete: Information processed by the students into conceptual frameworks is based on their perceptions of objects, events, persons, and places. Information is "discovered" to the extent that students interact with the objects or events directly to find new properties which they use to group objects into classes based on similarities or to order objects into a series.

Concrete Level: The students use reasoning processes to organize information into frameworks that are more complex because 1) they acquire the information indirectly through language and 2) they use definitional rules to form groups. A somewhat similar relationship to additive and multiplicative structures exists in the transition between the two levels of the concrete stage. At the concrete level the information organized into conceptual frameworks from the preceding level provides the anchor or examplars to form new groups.

Pre-systems: The students "discover" the parts of a structure or system by defining its related concepts. Through analogy, which is the reasoning process used to identify the component parts of different systems, a smooth transition can be made between the stages if there is continuous extension of the conceptual frameworks at the concrete level.

Systems: At this level, a system or structure is reconceptualized through hypothetical-deduction. A conceptual framework organized as a system is itself a premise, or hypothesized reality since a system is a construction of reality that cannot be observed. Comparisons with other systems provide 1) the basis for validation and 2) new information for reorganizing concepts into a system or structure which initially was constructed at the preceding level.

Within Level: In Piaget's stage theory the transition of preceding structures into higher stages is required to form a hierarchy of processes. While three interstage levels (pre-concrete, concrete, pre-systems and systems) provide for continuity between stages, they do not clearly differentiate between the formation and attainment of a stage. This requires analysis of the relationship between reasoning processes found within the level.

On the basis of how the information is organized in a framework, a reasoning process can be classified as definitive or explanative. A definitive framework, which is a structure composed on a number of similar groups, has two distinguishing characteristics: 1) the information which is organized into groups constitutes one whole, either a single concept, or a system composed of numerous concepts as shown in Diagram 2, and 2) the groups that form the framework are additive since they share one or more common characteristics.

In Diagram 1, the reasoning processes with definitive outputs precede the construction of explanative frameworks. A functional dependency exists between the reasoning processes of category, classify, and analogy and the processes where outputs link different, definitive wholes into a conceptual framework. Specifically, sequence and multiple association link dissimilar properties and problems at the concrete stage, and causality and hypothesis link subordinate groups of complex definitive concepts at the systems stage. At the highest level of the hierarchy, the reasoning processes of hypothesis and hypothetical-deduction combine both the processes for structuring definitive and explanative frameworks by 1) verifying the causal relationship which defines the condition of a structure

or system and 2) restructuring the parts of the system through a comparison of definitive structures. (A further description of the relationship between processes is found on the following pages.)

INFORMATIONAL CONTENT

The interdependency of the eight reasoning processes which result from the hierarchical organization of the stages and interstage levels only partially explains the continuity of information into more complex frameworks. In Diagrams 3, 4, and 5 on the following pages, the eight reasoning processes are organized horizontally into a sequence of two or more operations based on 1) the simple adding of properties and groups with 2) the integration of the dimensions of time and space into the hierarchical organization. At each level, as the outputs of the reasoning processes become more complex, the dimensions of time and space become increasingly important in sequencing each process into several operations.

Through the integration of the dimensions of topological space and time, it is possible to differentiate coordinate wholes or similar operations of one process. Each coordinate operation of a process is structurally the same but increases in complexity on the basis of the information. By associating the information of the operation with topological space and time, the operation becomes more complex with the increase in the distance between the student and the space and time represented by the information. This parallels Piaget's thinking that an increase in distance increases the difficulty of the interaction (1966, p. 150).

DIAGRAM 3 PRE-CONCRETE LEVEL INSTRUCTIONAL POPULATION - PRIMARY

Process	Operations			Key Actions and Instructional Questions
Multiple		Mu A1 Put two unlike objects together to explain an action.	Mu A2 Trace the steps in a series of continuous actions to the end result.	Link actions together. What causes a _____?
Sequence	$S_1 + S_2$ Order objects by one physical property. Order objects by two physical properties. Reverse	S_3 Order the classroom schedule for the morning-day. Order an event personally experienced into beginning, middle, end. Reverse	$S_4 + S_5$ Order an event that was observed into beginning, middle, end. Order the action of one actor in an observed act.	Order objects and events into a series. What are you putting in order?
Classify	$C^1_1 + C^1_2$ Group objects by one physical property. Group objects by two physical properties. Reverse	C_{1_3} Group objects by properties associated with location, usage, and role.	C^1_4 Group objects by three properties associated with location, usage and role.	Group objects by one or more physical properties.
Category	C_1 Sort objects into largest group.	C_2 Sort objects with one shared property into a two level hierarchy. Reverse	C_3 Sort objects with one shared property into a three level hierarchy based on location, usage or role. Sort each second level group into group based on physical properties.	Sort objects into two groups or more with one shared property. What objects go together?

*Objects is an inclusive term for things, places, events, and persons.

DIAGRAM 4 - CONCRETE LEVEL

INSTRUCTIONAL POPULATION - INTERMEDIATE

Process	Operations		Key Actions and Instructional Questions
	$Mu\ A_3 + Mu\ A_4$	$Mu\ A_5$	
Multiple Association	State one problem or outcome and two causes. State one cause for two outcomes or problems	State a series of related effects.	Link dissimilar concepts. What causes the _____?
	S_6	$S_7 + S_7$	
Sequence	Order a series of events.	Order the actions of two different actors within an event. Order the action of two different actors over a number of events.	Order a series of events and actions. How many events happened by time or within one place?
	Cl_5	Cl_6	
Classify	Group objects by two defining characteristics that describe the kind of group.	Group objects by location in geographical space.	Group objects by two defining rules - or characteristics. What objects have the same characteristics?
Category	Organize groups of objects into a three level hierarchy with physical properties the last level.	Organize groups of objects into a four level hierarchy with physical properties the last level.	Organize groups into a hierarchy. What are different kinds of groups?

DIAGRAM 5 - PRE-SYSTEMS AND SYSTEMS LEVEL — INSTRUCTIONAL POPULATION: MIDDLE AND HIGH SCHOOL+

Process	Operations		Key Actions and Instructional Questions
Hypothetical-Deduction H-D$_1$ 1) State a specific condition as a judgment. 2) Analyze structure or system by 1. naming concepts and 2. the parts of each concept. State differences between a similar structure or system that functions the opposite of the stated condition.	H-D$_2$ 1) State the needed changes in a specific system or structure. 2) Analyze and compare to different systems or structures that function for the same purpose to determine their concepts.	H-D$_3$ 1) State the relationships that describe 1. the problem, and 2. the system or structure. 2) Analyze and relate to the larger system or structure of which it is a part to determine how other concepts affect it.	Identify the parts of the system or the structure. What parts of the system should be changed?
Hypothesis H$_1$ State an educated guess about what is. Proof: defining concepts of a system or structure.	H$_2$ State an educated guess about how a problem or condition occurred. Proof: requires stating the effect related concepts have on each other.	H3 State an educated guess about why a problem or state occurs. Proof: a principle if numerous instances or examplars can be cited or a specific relationship between concepts.	Verify an educated guess about a problem or condition. How many different reasons can you give for the problem?
Causation	Cau 1 State 1 specific problem and the concepts (e.g. water pollution is defined by what concepts?) Determine parts of concepts which affect other parts.	Cau 2 State a problem or condition (e.g. high oil prices) and trace the series of events that caused it. Usually outside space and time of students.	Relate the parts of two or more concepts. What is the interaction?
Analogy A$_1$ Sort the systems and structures a person lives in (including human body) into largest groups. (Use cues of different tasks, e.g. voting - political systems)	A$_2$ Group the concepts or parts of a structure or system together. (e.g. technology)	A3 Compare the system or structure with similar ones in different space and time.	Group structures or systems that are alike. How are two or more systems or structure alike?

Coordinate operations, then, order the content of the information which the student processes from simple to complex based on the contact the student has with his environment through the information. For example, the operations of sequence in Diagrams 3 and 4, which require the student to order dissimilar objects or events, appear to be organized horizontally by the dimension of time. However, at the pre-concrete level, distance occurs through the student dissociating himself spatially from the event he experiences by becoming the observer of an event. At first, an event is conceptualized as a large, undifferentiated whole with only a beginning and end. The whole, then, is narrowed when the student analyzes an event he experiences into beginning, middle, and end and relates these parts to specific points in the event, for example the steps in writing a sentence.

Through the use of the coordinate operations of sequence, the student interacts with information to develop a continuous concept of reality. The coordinate operations of sequence transform the event into a structurally complex concept through the change in the content of the information. Therefore, students process different information but with similar conceptual frameworks. This strengthens the operations of sequence and also develops the operations of multiple association, which require the difficult process of linking two or more different conceptual frameworks in a causal relationship.

In Diagram 5 reasoning processes are organized into coordinate operations at the systems stage by combining topological space and time into one dimension. At the pre-systems level, time and space form historical, coordinate operations

for organizing processes into operations whose outputs and conceptual frameworks of systems. Future time and changes in conditions associated with topological space require that the students reason by hypothetical-deduction at the systems level based on systems constructed as coordinates at the preceding level.

Other than coordinate operations, the dimensions of topological space and time provide for a continuous assimilation of information through additive groups. Similar information but from different topological space can be related to concepts students have constructed. For example, in Diagram 2, different animals, which would be identified by the defining rule for mammals, could be grouped by different geographical spaces in a category structure to develop the concept of mammals at the concrete level. Historical time, which would be added to topological space at the pre-systems level, would be added to one or more concepts that form the multiplicative structure rather than conceptualizing the total structure in another time and space.

The integration of the dimensions of time and space with the reasoning processes place constraints on the content of the information which are essential to maintaining the hierarchy as an open system. It is an open system because a constant interchange of information is occurring between the students and their environment through the reasoning processes. As a result, the students can process information that continuously extends their definitions of the environment through constructing increasingly complex conceptual frameworks from the pre-concrete through the systems level.

Most of the instructional systems being used in classrooms organize information into concepts but not with information the student interchanges with the environment. The programs are essentially closed systems because they limit the contact the student has with his environment.

The hierarchy as an open system results in two important instructional outcomes:

1) The development of the adaptive ability of the student to function in the environment:

The student maintains a quasi-adaptive state of functioning before the systems level. At this level, the student possesses the structures of complex conceptual frameworks which are adequate to define the complex systems of the environment. Throughout life, the student has to continuously respond to the conditions of systems within the environment by assimilating new information and reconstructing the systems in which he functions. Otherwise, disequilibrium and malfunctioning can follow.

2) The use of conceptual frameworks to analyze the systems or structures in which the person functions:

Adaptation depends upon a conscious analysis of the operations of the systems in which the person functions. As previously discussed, a conceptual framework cannot be separated from the reasoning process that structured it. There is a functional interdependency between a conceptual framework, which is the output component of a reasoning process, and the process or action for constructing the output. When a person uses reflective thinking to consciously understand how to function, both components of reasoning are required. What the person

reflects on is the concept component or framework of structural relationships which Piaget (1966) maintains indicates intelligence. How the person reflects is through analysis of a concept which requires the action component of the reasoning process to restructure the already conceptualized framework. Instruction in reasoning processes, then, provides the conceptual structures the student uses to consciously reflect on the environment in which he functions.

IMPLICATIONS

Teachers have not been trained in processes for organizing information into concepts. Consequently, they confuse the assimilation of more information with concept development. For example, teachers have tried numerous instructional programs, particularly programs which emphasize information that interests the students. Usually the information in these programs have been organized into concepts, but the students do not process information by assimilating the information into their conceptual definitions of the environment. As a result, the instructional programs are closed systems since there is only a vague connection between the students and their conceptual frameworks, and limited contact between the students and the environment. Concept development requires more than information about the environment of the student. It requires the student to actively structure information into relationships that are his concepts of reality.

Instruction which results in the active construction of concepts is based on 1) thinking process, here reasoning, and 2) information associated with the

concept. The teacher must deliberately teach the reasoning process if the students are to process information into a concept. Therefore, instruction in reasoning processes should precede reading, which presently is considered the major process for gaining information. The students must first have a conscious process for organizing the information before they can be expected to assimilate the information into concepts.

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